Implications of Serial Discontinuity on Nonnative Fish Distributions in The Green River

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ABSTRACT

Before such drastic alteration to the watershed in the upper Colorado River Basin had occurred, it was a well-developed ecosystem characterized by a high level of endemism and a natural highly variable flow regime. For millions of years this ecosystem had been evolving to fit the physical stresses of this river and climate. During the middle of the last century human demands for power and water in the Southwestern United States prompted the 'taming' of this wild river system, which resulted in the construction of several dams and water diversions through out the Basin. Little was known about the affects these dams would have on native biota and the geological and hydrological characteristics of the rivers below.

Current research on the fish fauna of the Green River system is focused primarily on interspecific interactions, competition for resources, abundance and distribution of natives vs. non-natives, availability of quality habitat and any other information which may be relevant or insightful as to the mechanisms which may be responsible for the decline in the number of native fish in the Green River. This paper focuses on how anthropogenic and environmental factors coupled with the introduction of many non-native fish have affected native fish populations. In addition it discusses how the Serial Discontinuity Concept (Stanford and Ward 2001) predicts the distributions and proportions of populations and overall system biodiversity, to change due to the presence of the dam and compares that with the available information regarding current distributions and relative abundance of these fish.

INTRODUCTION

The original fish fauna of the upper Colorado River Basin consisted of an estimated 14 native species, including the following: mountain whitefish (*Prosopium Williamson),* the now extirpated Colorado cutthroat trout *(Oncorhynchus clarki pleuriticus),* speckled dace *(Rhinichthys osculus),* roundtail chub *(Gila robusta),* two species of commonly occurring suckers: the flannelmouth sucker *(Catostomus latipinnis)* and the bluehead sucker *(Catostomus discobolis)*. Four of the native species of fish are now federally listed endangered species:

Colorado pikeminnow *(Pytochocheilus lucius)*, bonytail chub *(Gila elegans)*, humpback chub *(Gila cypha)* and the razorback sucker *(Xyrauchen texanus)*. Numbers of bonytail are extremely low and they are now considered to be functionally extinct, an encounter would be highly improbable (Wintzer 2006). These fish evolved under extreme conditions while remaining very isolated for millions of years, which lead to their unique morphologies and life history strategies. Most frequently found in the river system are the now 25 common species of non-natives which compete with natives for crucial habitat and food (Muth et al. 2000). The foremost dilemma created from the presence of non-natives is their substantiated impact through predation, competition, and the spreading of disease to the native species population levels, given that these fish influence native numbers. These impacts must be taken into consideration when developing plans to manage their presence and to minimize their affects on native populations.

Populations of nonnative sport fish have previously been supported through stocking efforts. Now all state and federal agencies have agreed to cease stocking all nonnative fish, with the exception of trout, into the upper Colorado River Basin (Tyus 2000).

Variability of the flows in the river system were curtailed by the introduction of dams, this has created changes in the sediment load, temperature regime, and streambed composition and morphology. In addition the changes may have also resulted in loss of riparian and backwater habitat, which is crucial rearing ground for juvenile life stages of native fish as well as non-natives. This overlap of crucial habitat results in high levels of competition and predation (Karp 1990).

Of the cool- or warm-water nonnative fishes, red shiner (*Cyprinella lutrensis)*, common carp *(Cyprinus carpio)*, sand shiner *(Notropis stramineus)*, fathead minnow *(Pimephales promelas)*, and channel catfish *(Ictalurus punctactus)*, are widespread and common to abundant; redside shiner *(Richardsonius baleatus)*, white sucker *(Catostomus commersoni)*, black bullhead *(Ameriurus melas)*, northern pike *(Esox lucius)*, green sunfish *(Lepomis cyanellus)*, and smallmouth bass *(Micropterus dolomieu)*, are locally rare to common in some river reaches or habitats; and grass carp *(Ctenopharyngodon idella)*, Utah chub *(Gila atraria)*, creek chub *(pimephales notatus)* , Utah sucker *(Catastomus ardens)*, western mosquitofish *(Gambusia affinis)*, brook stickleback *(Culaea inconstans)*, bluegill *(Lepomis macrochirus)*, largemouth bass *(Micropterus salmoides)*, black crappie *(Pomoxis negronaculatus)* and walleye (*Sander vitreus)* are incidental to rare. Salmonids are generally restricted to the upper reaches of the river and are most abundant in the tail waters of Flaming Gorge Dam (Muth 2000).

Of the introduced species some have a greater impact than others: red shiner, common carp, fathead minnow, channel catfish, smallmouth bass, northern pike, and green sunfish are the non-natives considered by Colorado River basin researchers to be of greatest concern because of their suspected or documented negative interactions with native fishes (Hawkins and Nesler 1991). Representatives of the previously listed species, in addition to many others, will most likely be present in the stretch of the river below Flaming Gorge Dam to below the Yampa-Green Confluence. Distributions of these fish are subject to seasonal change. Fluctuations in flows and habitat plasticity may also have considerable affects on the range of a given species.

Impacts of Non-native abundance and distributions

As previously mentioned the non-native fish will compete for food and other resources, especially rearing habitat. Backwater habitats below the Yampa confluence are especially important nursery areas for young –of –year pikeminnow, there is intense predation upon larval and juvenile life stages of these fish, and potential of competition for resources and even space is high. The majority of the foods consumed by the fish in the backwaters are dipterans and their abundance may greatly affect the availability of food and increase levels of interspecific competition. Although diet overlap and diversity both appeared to increase in the lower reaches as opposed to the upper reaches of the river (Muth 1995). The greatest competitor with the natives for food is the red shiner (Muth 1995). There is much debate about which alien species affects the natives numbers most. Green sunfish or channel catfish are of large concern as they prey heavily upon juvenile and larval life stages of natives (Tyus and Sanders 2000). All introduced species have the potential to carry disease and pathogens, which may have a substantially larger impact on the native species than the non-natives. Most prey in some form on various life stages of the native fish.

Table 1. Predation of non-native species on native species

Native prey	Nonnative predators
Razorback sucker	Channel catfish, common carp, green sunfish, other sunfish, and largemouth bass.
Colorado Pikeminnow	Channel catfish, green sunfish, largemouth bass, smallmouth bass, black crappie, black bullhead, northern pike
Humpback chub	Channel catfish, black bullhead, Brown trout and rainbow trout, northern pike.
Bonytail chub	Channel catfish, black bullhead, Brown trout and rainbow trout, northern pike.

(Tyus and Sanders 2000)

Management

After attempts to control the alien fishes through mechanical removal and bag limit changes have proven mostly ineffective, it has become apparent that other changes to the system must be made in order to better control invasive population levels. In response to the growing nonnative populations a new flow regime is being implemented for the fist time this year with higher peak flows. It is hoped that these high flows will flush many of the nonnatives from the system, increase backwater habitat, and possibly restore some of the physical processes responsible for shaping this ecosystem to which the native big river fish are so well adapted (Muth et al. 2000). Other factors that may have contributed to the fishes' decline include pollution and introduced parasites. Among the chubs, hybridization may also be a factor (U.S. Fish and Wildlife service).

Changes in fish fauna should be fairly abrupt as the geography of the river has many diverse and distinct types of habitat in which these fish live. The variation in numbers of fish will likely correspond to the geographic and physical characteristics of the river. In addition factors such as water conditions and climate may affect these highly variable fish distributions.

OVERVIEW OF INFLUENTIAL INVASIVE SPECIES

Common Carp

The Common Carp is one of the most widely distributed fish in the world and is present in large numbers throughout many reaches of the Green River. These omnivorous bottom feeders will feed on eggs and larval stages of native big river fish (Tyus2000). Common Carp make up a large portion of the aquatic biomass found in the Green river, and their presence is sure to displace substantial amounts of native fishes. Because these occupy a great deal of habitat that would otherwise be suitable for Native chub and suckers their extirpation from the system would help to restore native population levels.

Red shiner

Red Shiners were introduced in to the Colorado River system in the late 1940's (Hayden 1992). The shiner is a small cyprinid and easily identifiable during the breeding season when their colors are most vibrant and breeding tubercles are present on the heads of the males. Their anal pelvic and pectoral fins have and orange tint. In addition they have read on the tops and sides of their head and purple crescents behind their opercles. They are a hardy baitfish capable of persisting in many atypical environments, but seem to avoid extreme conditions including cold clear fast flowing water (Moyle 2002). They do extremely well in backwater and slough environments that happen to be an area of limited availability in the Green river system. Red shiner are capable of reproducing several times in a summer which helps to facilitate their extremely high recruitment. Schooling behavior and frenzied feeding are common survival techniques employed by the red shiner. They have also been shown to display considerable amounts of aggression on native fish of similar size and are know to prey upon larval stages of native fish as well (Karp 1990).

Fathead minnow

Originally introduced into the Colorado River system in the 1950s as a bait source, Fathead minnow have become common throughout much of the watershed. Another small cyprinid species, the fathead minnow is identifiable by its thickened primary dorsal ray, a lateral band that does not typically extend past the anterior of the body. Their habitat preferences are much like that of the red shiner and although there is no specific account of their range or abundance in the primary stretch of the Green River, they are said to be present in high numbers in much of the backwater habitat (Muth 2000). They do not display as much aggressive behavior, or compete as intensely with native juveniles as the red shiner, but frenzied feeding is common among juvenile Fathead minnow (Karp 1990). Unlike many of the other fish in the system the fathead minnows provide parental care. They have notably high reproductive rates and in combination with their parental care make them extremely prolific. Fathead minnows are often the first species to colonize and last to leave under intermittent conditions (Moyle 2002).

Other invasive cyprinids

Redside shiner and sand shiner are also commonly found in the stretch of the river where our observations will take place, however their impacts and interactions with the native fish species are not as well understood as the other small cyprinids with which they share much of the backwater habitat (Karp1990).

Smallmouth Bass

In the Green river, large concentrations of smallmouth bass care present and may congregated near any aquatic vegetation and rocky structure found in the main channel where water temperature has reached at least 20°C(Moyle 2002). These centrarchids were intentionally stocked in the system for many years, and although stocking has ceased they maintain recruitment by spawning in the river and reintroduction from off-channel impoundments (Tyus 2000). High fecundity and long lives make this species extremely difficult to extirpate from the main channel. These fish typically prefer clear water with a rocky bottom, but seem to do well in the turbid waters of the Green River. They are carnivores, and their diet is typically comprised of crayfish, large insects and fish, they prey on various life stages of the native species, including larvae, juveniles, and small adults (Tyus 2000). The U.S. Fish and Wildlife Service feel that smallmouth bass and Northern pike pose the largest threat to native populations (U.S. Fish and Wildlife Service 2002).

Channel Catfish

With its elongate bottom rover body shape, deeply forked tail, lack of scales, spotting and barbels channel catfish in the Green river should be easily identifiable. Their morphology allows them to reside in the main channel of streams and rivers, lying in pools behind cover and structure during the day while they forage and feed nocturnally. They prefer warm clear streams and rivers, but they are capable of surviving in harsh environments with muddy turbid water and low dissolved oxygen levels. Channels catfish have historically been widely recognized as omnivores but much of their plant and detritus ingestion is believed to be accidental (Moyle 2002). Their use of barbels to identify food in conditions with poor visibility in conjunction with their tendency to feed nocturnally may explain this believed accidental consumption. Fish become an important part of their diet as they grow and they tend to be mainly piscivorous once they reach a length of around 42 cm, at which point they begin to prey heavily upon juvenile and larval stages of all native big river fish (Tyus 2000). Although full-grown adult pikeminnows have few predators, they have been shown to choke on large channel catfish; this may having an impact on adult pikeminnow numbers, and in addition may reduce predation on channel catfish in general (Ryden 2002). As pikeminnow numbers decline the adults in the population become increasingly more valuable. The extent of the affects channel catfish presence may have on native populations is, however, unknown (Wintzer 2006). In the upper reach of the Green River channel catfish are quite common, with their presence becoming more prevalent below the Yampa Confluence.

Northern Pike

Esox lucius were introduced into the watershed in 1977 when they were stocked in Elkhead reservoir on the Yampa River drainage. Four years later, in 1981, they were found in the Green River. Following stocking efforts numbers had risen to high enough levels to establish a sport fishery. Although stocking efforts have ceased northern pike are known to spawn in the River channel (Tyus 2000). However, the U.S. Fish and wildlife service maintains that recruitment is low. These voracious predators have become a growing problem among watersheds across the Western United States. Natives of Northern Eurasia and North America as well, they are present in all of the Great Lakes. They are easily recognizable with their large duckbill like snout, which may be over half the length of the head. Their coloring varies spatially and temporally but typically is a variant on a dark olive or grey top which lightens becoming white on the ventral side of the fish. They prefer environments like those of cool clear lakes and sluggish streams, and gravitate towards aquatic vegetation. They are lie-in-wait or ambush predators. As is apparent from their large eyes they rely on their vision to identify and capture their prey and thus prefer the clear water. Their temperature preferences range per life stage with adults preferring increasingly cooler temperatures, but are quite tolerant of most temperatures ranging from 19-30 degrees Celsius (Moyle 2002). Pike are highly pisciverous but are also known to consume amphibians, reptiles, small mammals and other pike. Diets of pike in the Green river are comprised mostly of small minnows and suckers (Tyus 1990). They reach sexual maturity at 2-3 years of age, and provide little to no parental care for young (Moyle 2002). Abundance in the Upper Green River is rare to incidental, but due to increased recruitment from Yampa River populations, and an increase in available habitat it is likely that their presence will gradually increase below the confluence.

Green Sunfish

Green sunfish could prove to be the most problematic invasive species to manage in the system (Tyus 2000). These deep-bodied sunfish are highly recognizable with their dark olive coloration and unique body shape. They have characteristic iridescent green streaks along their cheeks and body. Native to the Mississippi drainage system, they have been introduced and persist in nearly every state in the nation. They prefer small warm streams with low flows as their body shape makes them inefficient swimmers in more rapid flowing waters. Green Sunfish are noted for their ability to persist in typically poor conditions with high turbidity and low dissolved oxygen. They are able to spawn in areas that are unsuitable for most other species (Moyle 2002). They are known to congregate near beds of aquatic vegetation. They are extremely aggressive fish and tend to be territorial for feeding, and often show aggression to other species of fish that may be invading their space (Moyle2002). They are extremely abundant in areas, and inhabit much of the backwater habitat throughout the entire system (Tyus 2000).

A BIT ABOUT NATIVES

The Native fish of the Green River were extremely adapted to the competition and abiotic conditions of their system. Prior to the invasion of nonnative fish, large Pikeminnows were the main predator in the river. Their ability to consume fish was size limited by the acute gape of their jaw. In addition to their gape limitations, their lack of jaw teeth makes prey manipulation difficult and may be yet another piece in the puzzle of explaining their lack of dominance as predatory fish in a system dominated with spiny-rayed centrarchids, which may prove difficult to swallow (Portz 2004). The Suckers and chub in the system had exploited this weakness in the predator arsenal of the pikeminnow by adapting to grow a large hump soon after leaving their juvenile rearing habitat. Pikeminnow predation is believed to be the mechanism responsible for the hump on the native big river fish, as well as their utilization of backwater habitat for their juvenile's nursery habitat, both created physical barriers that prevented predation (Portz 2004). Pikeminnow predation was the primary biotic mechanism in the selection of these native fishes morphology.

DISEASE AND PARASITES

It is undeniable that the invasive species presence in the Green River system is having huge impact on the presence of the native populations, however it is difficult to quantify the affects invasive presence has on native numbers. Perhaps the least understood aspect of the interspecific interactions is the role disease and parasites, brought into the system by these invasive fish. In a study determining the diet composition of pikeminnow in comparison with six other nonnative species common to the Green River cestodes were found in the gut contents of six Colorado pikeminnows and were absent from all other fish (Muth 1995). Asiatic Tapeworm is another pathogen thought to be introduced by the Red shiner, it has shown up in many species present in the system, such as: grass carp, common carp, roundtail chub, bonytail chub, golden shiner, fathead minnow, Colorado Pikeminnow, green sunfish and even western mosquito fish (Heckman 1986). It greatly reduces the fitness of carriers and frequently leads to death.

Attempts to maintain native population numbers through the stocking of hatchery reared razorback suckers. I was discovered that these fish are susceptible to “white spot disease” which is fatal and contagious (Karp 1990). Although this disease is common among hatchery raised fish spreading it to wild populations could reduce recruitment even further.

MANAGEMENT OF NON-NATIVES

Since the listing of the four native big river fish: the Colorado pikeminnow, bonytail and humpback chub, and razorback sucker, there have been many methods employed which it was hoped would control population levels of the non-native fish. The most common methods employed by the U.S. Fish and wildlife service include electro-fishing, block netting and seining of backwater habitats. Unfortunately, many alien fishes are now well established within the system which makes the task of removing them using current techniques very labor intensive, cost ineffective and nearly impossible. Management of the river system should be focused on promoting native fishes and suppressing alien fishes if the Upper Colorado endangered fish recovery plan is to be successful. Several mechanisms have been recommended for suppressing alien fishes including fluctuating flows, temperature changes, and sediment augmentation, in addition to mechanical removal of alien fishes. Past experiments, such as the flood of 1996, and mechanical removal of alien fishes in the Grand Canyon show that these methods may work in suppressing some alien fishes (Muth 2000).

The United States Fish and Wildlife Service has determined that increasing floodplain habitat will have a positive impact on the Native populations. They say specifically:

> "Habitat enhancement in the Green River sub-basin has also addressed floodplain restoration. Inundated floodplains provide critical nursery and adult habitat for endangered fishes. Floodplain restoration actions have included breeching or removal of several levees to increase the frequency floodplain connection to the river, and improvement of water control structures to increase management options on the Ouray National Wildlife Refuge and adjoining Bureau of Land Management lands on the Green River. In addition, wildlife easements are purchased from willing landowners to increase river connection to important floodplains. Research by the Vernal CRFP and other program participants has shown that floodplains will play a major role in recovery of endangered fishes…"

On 4/21/2006 The Upper Colorado River Endangered Fish recovery program declared that the new focus of their research would be the management and removal of nonnative Northern pike and Smallmouth bass (U.S. Fish and wildlife service).

BIODIVERSITY

The American Fisheries Society (AFS) stance on the preservation of biodiversity warns that "Biodiversity should not be likened to an often transitory increase in the variety or numbers of species through the introduction of nonnative plants and animals…Biological integrity is defined as the capacity to support and maintain a balanced, integrated, adaptive community with a biological composition and functional organization comparable to those of natural waters of the region" (Winter and Hughes 1995). Biodiversity can be measured on many scales, but we should concern ourselves most highly with loss of biodiversity on a global scale. Loss of biodiversity may degrade global biological integrity, resulting in the loss of genetic material created by millions of years of evolution. This genetic information is believed to hold vast amounts of information that may benefit humanity in the discovery of medicines, food sources, industrial products, and much more.

The ability of an area to maintain homeostasis under nearly natural conditions is considered its biological integrity. As the integrity of a system is lost so leaves the adaptivity of the system, along with the functional organization of the community. In this way the system loses the crucial mechanisms that maintain the processes driving selection within it and preserving genetic information.

IMPLICATIONS OF SERIAL DISCONTINUITY

The Serial Discontinuity concept is based on the notion that rivers have an innate tendency to reset ecological conditions toward natural or unregulated conditions as distance downstream from a dam increases, resulting in an increase in water temperatures as they reach an equilibrium with ambient air temperature and turbidity is restored as sediments loads of tributaries are dumped into the main channel. At which point affects of the damn on fish distribution and abundance should be minimized or negligible. These conditions resembling the natural flow of the river should be reached by the time the Green River is met by the Yampa. Alterations of flow regimes may help to return the river to more *natural* conditions, at a shorter distance from the dam, which may restore the processes responsible for shaping and developing the system. However, there is no way of knowing how such a drastically altered ecosystem may react to those changes. There will be a system wide increase in biodiversity as we travel farther from Flaming Gorge, as there is a greater amount of overlap in viable conditions for different species over a smaller area.

Further examination and discussion among the scientific community is crucial if hopes preserving these dwindling fish populations are to be realized. In addition more research in this system could provide mankind with a better understanding of how our actions can affect entire ecosystems, which will hopefully lead to a more eco-minded society, focused on making more informed decisions which may help to sustain and protect the great biodiversity present on our planet.

CONCLUSION

Nonnative fishes dominate the ichthyofauna of Colorado River Basin Rivers and have been implicated as contributing to reductions in the distribution and abundance of native fishes as a result of competition and predation (Carlson and Muth 1989) The recent proliferation of these species is a result of dramatic changes in flow regimes, water quality, and habitat characteristics. I do not believe that any actions taken short of the removal of Flaming gorge dam will ever restore the populations of native fish to their historic numbers, nor would the removal of the dam guarantee the recovery of native populations as their ecosystem has undergone such alteration. The reality is that the characteristics of the river have been altered so drastically that preserving sustainable population numbers must be our best opportunity to preserve these beautiful fish. Management techniques are varying in Recovery plans For Colorado River endangered fish species they include more restrictive stocking protocols, reduction or elimination of escape from existing stocks, more liberalized harvest regulations, mechanical removal, chemical eradication, and management of flows to benefit native fishes and suppress the abundance of nonnative fishes. Hopefully the implementation of the 2000 flow recommendations this year, 2006, will benefit native species as predicted, as high spring flows have been shown to have a neutral to positive effects on native species while reducing numbers of non-natives presumably due to undesirable temperature fluctuations which may hinder their ability to reproduce, flushing the fish out of the river due to flow velocity, or reducing backwater habitat where most of these fish reside, but is most likely a combination of all three hardships which make it difficult for these non-natives to overcome.(Muth et al. 2000).

It is apparent from the vast amounts of time, money and resources invested by State and Federal agencies, that the presence of these native fish is an issue of growing importance. Increasing public knowledge of this issue may aid in the allocation of more resources and greater co-operation from the general public in the implementation of new policy. A combined effort from our nation may prove to be too little too late, however I hold on to the hope that my children and grandchildren will one day have the opportunity to observe the native big river fish which were once so prolific in the waters of the Green River.

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